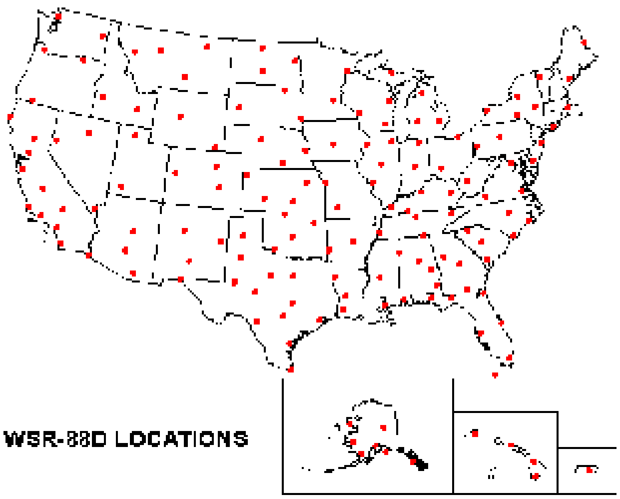
WSR - Weather Surveillance Radar



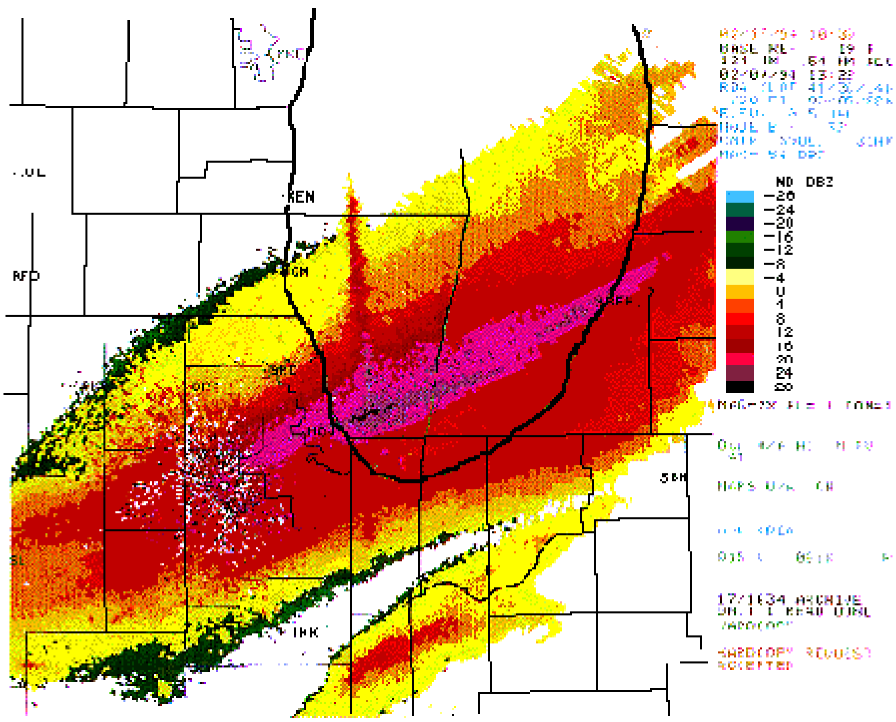
It was learned during World War II that electromagnetic radiation could be sent out, bounced off an object and returned to a listening device. By timing the time it took for the energy to travel to the target and back (hence the word *echo*), one could give a location of that object. **Radar** is an acronym for **Ra***dio* **D***etection* **a***nd* **R***anging*. It was soon learned that raindrops made excellent targets for S-Band radar (~10cm) and thus weather radar units were set up across the United States in the mid 1960's. Recent advances in technology has resulted in a new system of Doppler radars installed across the US in a program called **NEXRAD**, for **Nex***t Generation Weather* **Rad***ar*. The new radars would be co-located with modernized weather service offices to help usher in the new millennium with unprecedented radar coverage. The new radars were WSR-88D - the D standing for Doppler. These Doppler radars would replace the conventional non-coherent radars from 1957.

Benefits of the WSR-88D over the WSR-57

- **Improved Sensitivity** - This is basically a result of a greater amount of power transmitted and a greater ability to distinguish smaller returns. The WSR-88D's ability to detect lighter amounts of precipitation has allowed for the detection of very light precipitation and even subtle clear air boundaries.
- **Improved Resolution -** This is primarily a function of angular beam width. The narrower the beam, the smaller the width at a given distance. This will allow the WSR-88D to differentiate between objects, thereby increasing the resolution.
- **Volume Scanning -** Rather than scanning along varying azimuth angles (PPI) then stopping to scan vertically (RHI), the radar will automatically scan various elevation angels while spinning around 360° of azimuth. Computers will generate products based on this volume scan.
- **Enhanced Capabilities and Algorithms -** Sophisticated computer programs will assist the radar operator to detect various phenomena such as mesocyclones and tornadoes (Tornado Vortex Signature - TVS) and the like. The radar will also have a greater range of reflectivities operating in severe and non-precipitation modes.

The following is a breakdown of reflectivity (in dBZ's) corresponding to various Video Integrator and Processor (VIP) levels of the WSR-57. The WSR-88D's will have fifteen different levels. The minimum detectable reflectivity for the WSR-57 was 18 dBZ whereas the minimum detectable return for the WSR-88D is -28 dBZ.

VIP Level	*Equivalent Reflectivity (Z_e)*	*log Z_e*	*dBZ (10xlog Z_e)*
1	0 - (1000)	0 - (3)	0 - (30)
2	1000 - (12,589)	3- (4.1)	30 - (41)
3	12,589 - (39,811)	4.1 - (4.6)	41 - (46)
4	39,811 - (100,000)	4.6 - (5)	46 - (50)
5	100,000 - (501,187)	5 - (5.7)	50 - (57)
6	501,187 or more	5.7 or more	57 or more



SOUTHWEST-NORTHEAST ORIENTED SYNOPTIC SCALE SNOW WITH NORTH-SOUTH MID-LAKE 'LAKE EFFECT' SNOWBAND. NOTE THE INCREASED REFLECTIVITY AT INTERSECTION EAST OF MIDWAY AIRPORT (MDW).

The above radar report shows a lake-enhanced snowfall. Imagine what the image would be like if nothing under 18 dBZ's showed up as echoes! The new WRS-88D's are a great improvement for snowfall observation. Because of the sensitivity of the radar for slight echoes, the non-precipitation mode is often used for snowfall. Heavier rainfall, and especially hail show up well in severe weather mode.

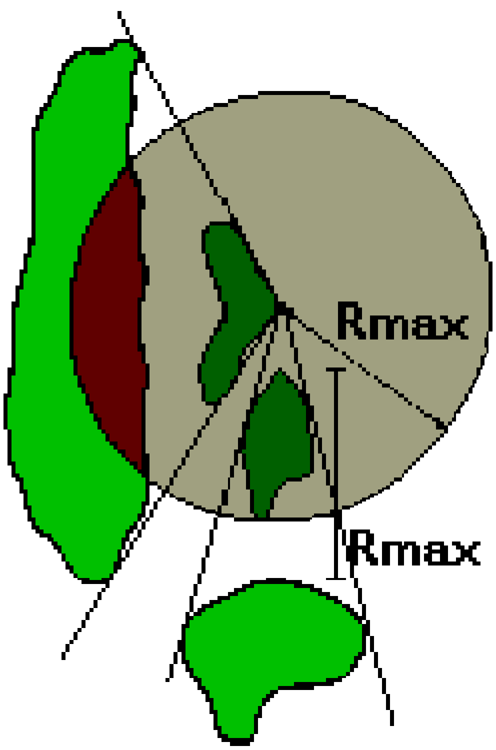
The maximum unambiguous range, Rmax, corresponds to half the distance electromagnetic energy can travel between pulses (since the energy needs to travel to the target and back). The pulse repetition frequency (PRF) is a measure of how frequently the pulses are transmitted. If c is the speed of light (taken as $3x10^8$ ms^{-1}), then

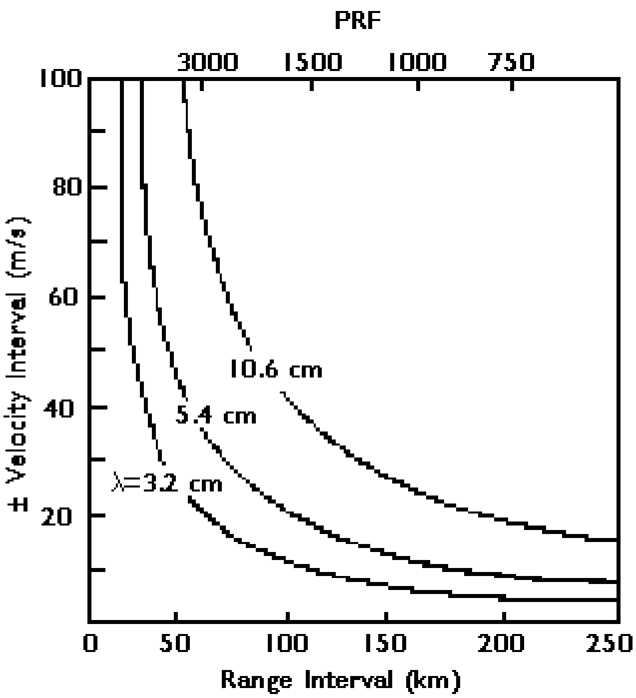
$$R\max = \frac{c}{(2 \times \mathrm{PRF})}$$

In words, the maximum unambiguous range is inversely proportional to the PRF.

Radar	PRF(pulses per sec)	Rmax(km)	Rmax (nmi)
WSR-57	164 or 545	915 or 275	494 or 149
WSR-74C	259	579	313
WSR-88D	318-1304	471-115	254-62

If a second pulse is transmitted before energy from the first pulse has been received, the echo from a target beyond the maximum unambiguous range is displayed at the proper azimuth but at a distance one Rmax closer to the radar. This "second-trip echo" exemplifies *range folding*. Echoes may be folded from third and fourth trips if the Rmax is small enough to allow for targets to be observed at multiple intervals of Rmax.





Average Power Return

A radar is able to detect a small amount of power returned from a target. Obviously, the more sensitive the receiver, the more a radar is able to detect smaller or less efficient scatterers. The radar needs to average returned power from many successive pulses since the power returned from pulse to pulses is highly variable. The WSR-88D will typically average power from 25 pulses to determine a representative value. A radar can increase its ability to detect a target by not only changing its listening ability, but by maximizing the power it transmits. The greater the output, the greater the return.

Maximum Transmitted Power

Whereas the power output of the WSR-57 is 410,000 watts, the output of the WSR-88D is 750,000 watts. The return power is directly proportional to the transmitted power.

Antenna Gain

Gain is a measure of the antenna's ability to focus the radiated energy. The antenna's gain indicates the relative amount that the energy is focused compared to what it would be if it were an isotropic radiator (giving off radiation equally in all directions). The gain of the WSR-88D is 35,481 (compared to the WSR-57 with a gain of 6,460), meaning a target will be struck with over 35,000 times more energy than it would without a dish. Power received from a given target is directly related to the square of antenna gain.

Angular Beam Width

Power returned to a radar is directly related to the square of the angular beamwidth (assuming a beam narrower than 2° and at a range less than 125nmi). A narrower beam will improve sensitivity by focusing the outgoing power and increase the resolution by decreasing the size of the beam's cross-sectional area.

Radar	***Wavelength (cm)***	***Dish Diameter (feet)***	***Angular Beam Width (degrees)***
WSR-57	10.3	12	2.0
WSR-74C	5.4	8	1.6
WSR-88D	11.1	28	0.95

Range		***2.0 degree beam***		***0.95 degree beam***	
(nmi)	(km)	(feet)	(m)	(feet)	(m)
50	93	10613	3235	5041	1536
100	185	21227	6470	10082	3073
150	278	31840	9705	15124	4609
200	371	42454	12980	20165	6165
250	463	53067	16175	25206	7683

Pulse Length

The radar transmits energy for a given period of time known as the transmission time. When that is multiplied by the speed of light, a train of energy, or pulse, extends outward from the antenna with a pulse length, H. Long pulses are used to determine target locations, while short pulse lengths help determine target intensity and motion characteristics. The power received from a target is directly related to pulse length. The longer the pulse length, the more energy is being transmitted. This will improve the sensitivity of the radar.

Radar	Transmission Time (microseconds)	Pulse Length (km)
WSR-57	0.5 or 4	0.15 or 1.2
WSR-74C	3	0.9
WSR-88D	1.57 or 4.5	0.47 or 1.35

Contiguous Surveillance

- Reflectivity
- Low Pulse Repetition Frequency (PRF)
- Unambiguous Range of 248nmi (460 km)
- Used at Low Elevation Angles

Contiguous Doppler

- Velocity

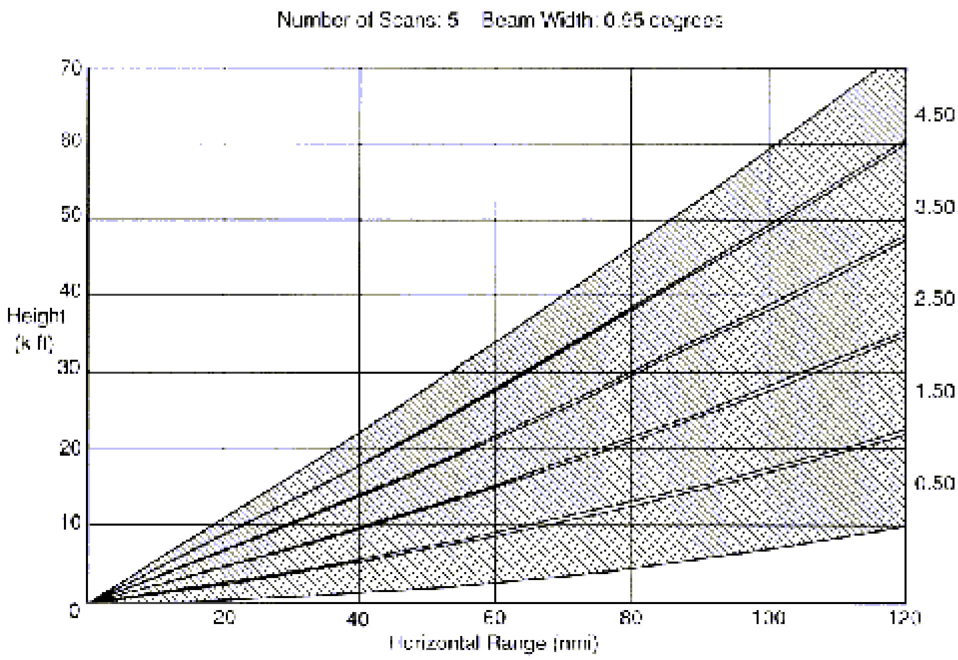
- High PRF
- Shorter Unambiguous Range
- Used Primarily at Low and High Elevation Angles

NEXRAD Information Dissemination Service (NIDS)
See here for examples.

- Reflectivity(2 tilts) 1x1 km, 16 data levels, 230 km range
- Composite Reflectivity 4x4 km, 16 data levels, 460 km range
- Echo Tops
- Vertical Integrated Liquid (VIL)
- Surface Rainfall Accumulation
- 1-hr Running Total
- 3-hr Total (once per hour)
- Storm Total Rainfall
- Hourly Digital Rainfall Array Product
- Radial Velocity (2 tilts) 1x1 km,16 data levels, 230 km range
- Velocity Azimuth Display (VAD) Winds (Time vs Height)
- Layer Composite Reflectivity

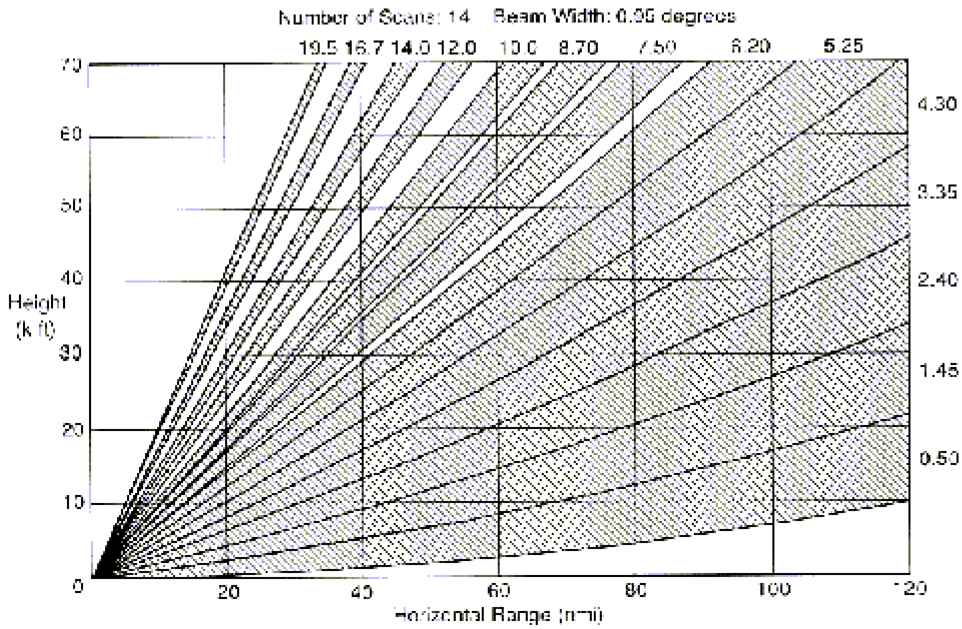
Operational Modes

1. ***CLEAR AIR MODE***
   1. ***Volume Coverage Patterns***
      1. **VCP 31**
         1. 5 Elevation Angles
         2. 10 Minute Volume Scan
         3. Long Pulse (Higher Sensitivity)
         4. Lower PRF (More Velocity Aliasing; Less Range Folding)
      2. **VCP 32**
         1. 5 Elevation Angles
         2. 10 Minute Volume Scan
         3. Short Pulse (Lower Sensitivity)
         4. Higher PRF (Less Velocity Aliasing; More Range Folding)



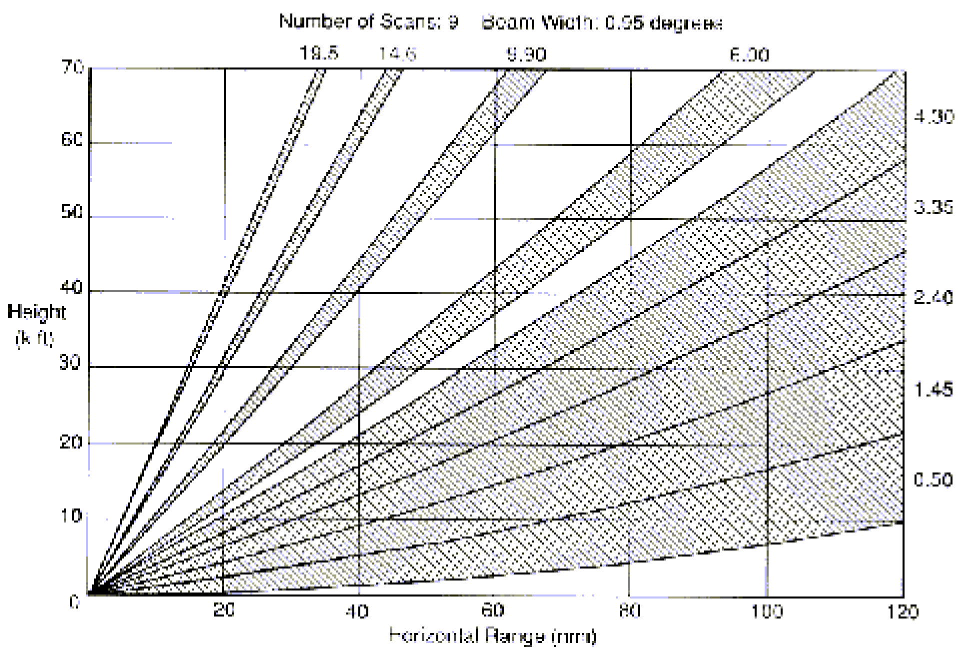
Clear Air Scan
Volume Coverage Patterns 31 and 32

1. ***PRECIPITATION/SEVERE WEATHER MODE***
    1. ***Volume Coverage Patterns***
        1. **VCP 11**
            1. 14 Elevation Angles
            2. 5 Minute Volume Scan
            3. Short Pulse (Lower Sensitivity)
            4. Varying PRF's

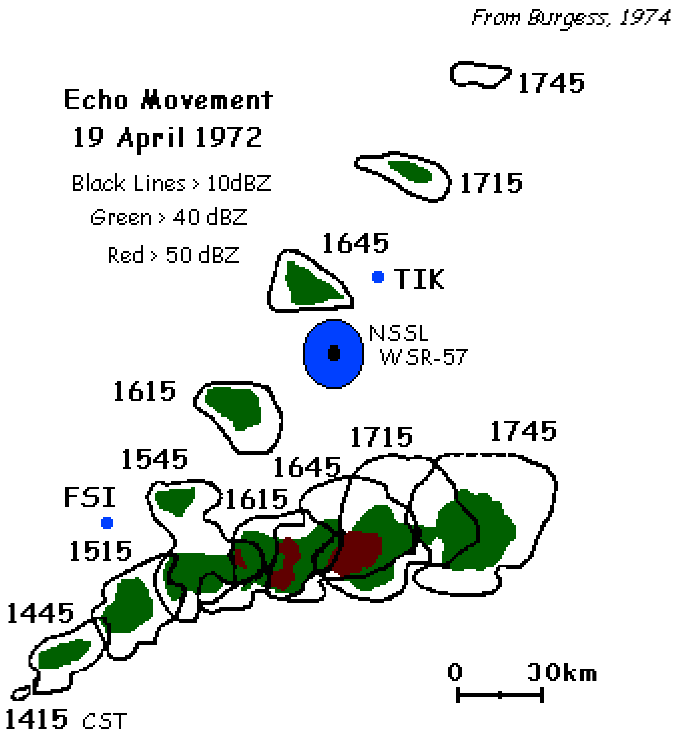


Precipitation/Severe Weather Scan
Volume Coverage Pattern 11

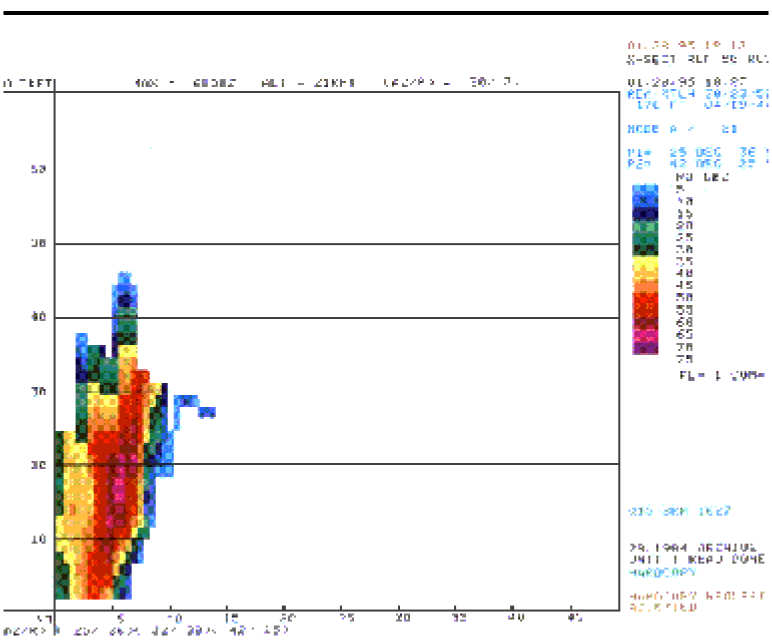
1. **VCP 21**
    1. 9 Elevation Angles
    2. 6 Minute Volume Scan
    3. Varying PRF's



Alternative Scan
Volume Coverage Pattern 21



Example of a splitting storm. Notice how the right splitting storms slows down and intensifies while the left splitting storm accelerates and weakens as its storm relative inflow weakens.



RHI scan. Notice the mid-level echo overhang at 9 nmi. This is a good example of a WER. Also, note that +50dBZ returns extend over 30,000 ft.